IN BEAM γ-RAY SPECTROSCOPY OF VERY NEUTRON DEFICIENT ODD-CADMIUM ISOTOPES *

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Excited states in the very neutron deficient odd cadmium isotopes ^{99}Cd, ^{101}Cd and ^{103}Cd are discussed in terms of the nuclear shell model. Systematics of excited states in $^{99-109}$Cd is presented.

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1. Introduction

A substantial progress has been achieved recently in experimental investigations of excited states of nuclei in the region of ^{100}Sn. In particular, cadmium isotopes have been studied extensively. In this presentation we summarize the results of our studies of the three most neutron deficient odd-cadmium isotopes ^{99,101,103}Cd [1–3] and we discuss the systematics of odd-cadmium nuclei up to ^{109}Cd.

2. Experiment and results

An experiment was performed in order to study excited states of nuclei in the vicinity of ^{100}Sn. A beam of ^{58}Ni was used to bombard a ^{50}Cr target, leading to the compound nucleus ^{108}Te. The NORDBALL detector array combined with charged particle and neutron detectors was used. Experimental details are given in papers [1–4] and in the references therein.

Two α particles and one neutron had to be evaporated from the compound nucleus in order to produce ^{99}Cd. The relative yield for the production of this nucleus was about $8 \cdot 10^{-5}$. Excited states of ^{99}Cd have been identified for the first time [1]. Five excited states have been found, extending the level scheme up to 2.7 MeV.

The ^{101}Cd nucleus was produced with the emission of 2 protons, 1 α-particle and 1 neutron. The relative yield was about 3 %, one third of events contained at least two γ rays registered in the Ge detectors and were suitable for the $\gamma\gamma$coincidence analysis. The yield was large enough to create $\gamma\gamma$-coincidence matrices almost uncontaminated by γ-rays from other nuclei and to extend the level scheme up to the excitation energy of about 7 MeV [2].

The ^{103}Cd nucleus was produced in one of the strongest reaction channels, with the relative yield of about 15% (or 5% if only events with at least two γ rays are included). Four protons and one neutron were evaporated from the compound nucleus. The level scheme was significantly extended [3].

3. Shell model discussion and systematics

Selected experimental excited states of ^{99}Cd, ^{101}Cd and ^{103}Cd are plotted in Fig. 1. These are compared to the results of the shell model calculations. The calculations were done using the code RITSSCHIL, details of the calculations can be found in Refs. [2, 3, 5]. The discussion presented below is extended to heavier cadmium isotopes and the systematics of yrast states in $^{99-109}$Cd is shown in Fig. 2. The discussed nuclei are interpreted in terms of neutron–particle and proton–hole excitations with respect to the doubly magic ^{100}Sn core.

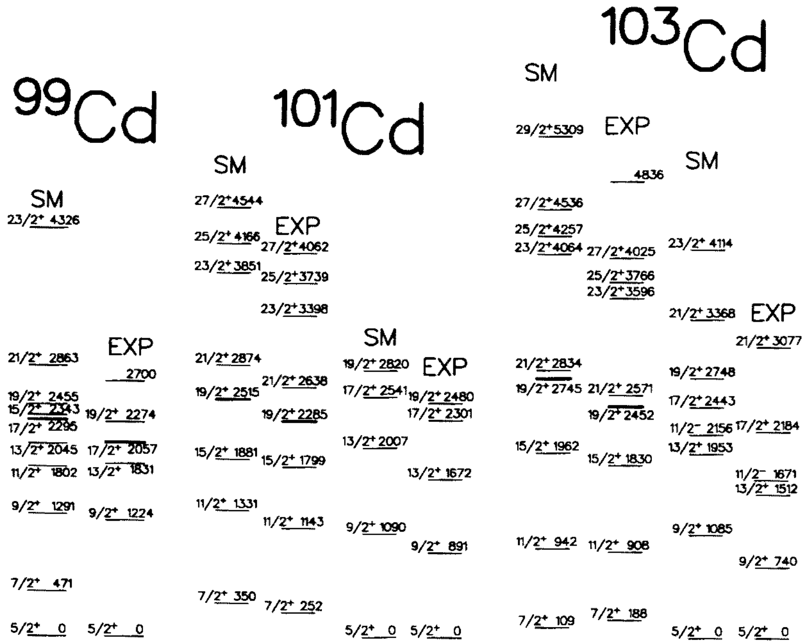

Fig. 1. Selected experimental excited states in ^{99,101,103}Cd and states calculated in the framework of the shell model.

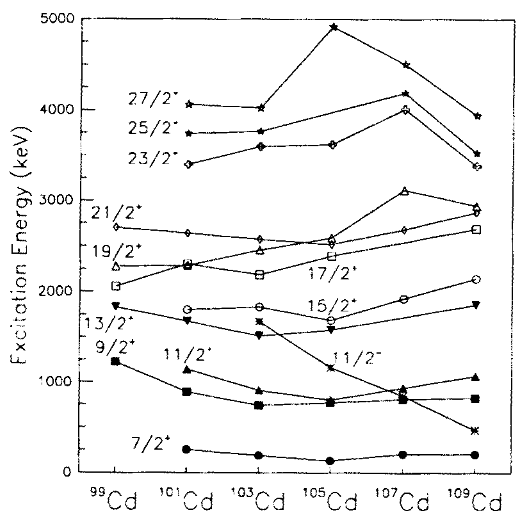

Fig. 2. Systematics of excited yrast states in $^{99-109}$Cd.

The calculations reproduce relatively well the experimental states. On top of the qualitative agreement, systematic discrepancies are observed. The spacing between calculated states is generally larger than the spacing between the experimental levels. This discrepancy is mainly attributed to the proton two body matrix elements (TBME). As presented during this conference by Górska *et al.*(see also [6]), the recently established level scheme of ^{98}Cd is best reproduced in the calculations using a set of proton TBME given by Blomqvist and Rydström [7] whereas the proton TBME from the work of Gloeckner and Serduke [8] are used here.

A tendency to overestimate in the calculations energies of the lowest excited states in nuclei in the region is more general, and in particular an effect of this kind is observed for indium nuclei, including the recently studied one–proton–hole, two neutron particles nucleus ^{101}In [4]. A systematic feature of the calculated wave function of the ground states of the nuclei in this region is that two negative parity orbitals may contribute significantly to these wave functions. These are the proton–hole $p_{1/2}$ and neutron particle $h_{11/2}$ orbitals. They contribute to the ground state wave functions with two particles (or holes) coupled to low spin values (mainly spin equal 0). A possibility exists, that this contribution may lead to the lowering of the ground state energy and thus shifting all other states up. Neither the neutron $h_{11/2}$ and the proton–hole $p_{1/2}$ single particle energies nor the $\nu h^2_{11/2}$ and $\pi p^{-2}_{1/2}$ TBME can be experimentally verified in a straightforward way in the region of ^{100}Sn, at present.

It can be seen in Fig. 2 that the general layout of the positive parity states is rather similar for all the nuclei considered, up to ^{109}Cd. The spin of the ground state is determined by the odd neutron particle placed on the $d_{5/2}$ orbital. The first excited $7/2^+$ state is due to the excitation of the odd neutron to the $g_{7/2}$ orbital. Some of the higher lying excited states can also be interpreted as belonging to one of the two groups: with the odd neutron either in the $d_{5/2}$ or $g_{7/2}$ orbitals. Qualitatively, the states $9/2^+$, $13/2^+$, $17/2^+$ are of the $d_{5/2}$ type, whereas the states $11/2^+$, $15/2^+$ could be assigned the $g_{7/2}$ character. More detailed insight into the calculated wave functions shows that some of these states are strongly mixed, and in particular the $15/2^+$ state in ^{99}Cd has almost equal contributions of the two configurations. The $g_{7/2}$ type states are not observed in ^{99}Cd.

The structure of odd-cadmium isotopes is strongly influenced by a strong two body interaction in the aligned $(\pi g^{-1}_{9/2} \nu d_{5/2})_{7^+}$ configuration. The $17/2^+$ state, which is the lowest state with a significant contribution of the $(\pi g^{-1}_{9/2} \nu d_{5/2})_{7^+}$ configuration, is shifted down with respect to the $15/2^+$ and $13/2^+$ states. The energy of the E2 transition $17/2^+ \rightarrow 13/2^+$ is thus low, and an M1 transition to the $15/2^+$ state is not energetically possible. This results in the observation of the 13.1 ns half-life of the $17/2^+$ state.

Both, the $19/2^+$ and $21/2^+$ states, have dominating wave function components including the $(\pi g_{9/2}^{-1} \nu d_{5/2})_{7^+}$ configuration. The unobserved $23/2^+$ state in ^{99}Cd is built on a pure, stretched $(\pi g_{9/2}^{-1} \nu g_{7/2})_{8^+} \pi g_{9/2}^{-1}$ configuration. A different character of the proton–hole neutron–particle interactions for the $d_{5/2}$ and $g_{7/2}$ neutrons, results in a large energy gap between the $21/2^+$ and $23/2^+$ states.

The $17/2^+$ isomer is not observed in the heavier isotopes, due to a generally more mixed character of the wave functions. The $21/2^+ - 23/2^+$ energy gap is observed in ^{101}Cd and in the heavier isotopes and this suggests that the three quasi–particle interpretation remains partly valid for excited states in $^{101-109}$Cd.

The $19/2^+$ isomer observed in ^{101}Cd and ^{103}Cd (4.5 and 1.3 ns, respectively) is of a different character than the $17/2^+$ isomer. The retardation of the $19/2^+ \rightarrow 15/2^+$ transition is the result of the fact, that yrast states below $19/2^+$ are built on configurations with angular momentum generated by a neutron pair, whereas the $19/2^+$ state involve the stretched $(\pi g_{9/2}^{-2})_{8^+}$ configuration.

Negative parity E2 bands have been observed for ^{103}Cd and all the heavier isotopes discussed here. The structure of the negative parity bands is still an open question and this is discussed elsewhere — see Ref. [3] and references therein.

In conclusion, the level schemes of the very neutron deficient odd cadmium isotopes $^{99-103}$Cd have been recently much extended. The structure of the positive parity states in these nuclei is relatively well understood in terms of the nuclear shell model.

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